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SESSIONS OF THE DEPARTMENT OF PHYSICOMATHEMATICAL SCIENCES, ACADEMY OF SCIENCES USSR

Yu. D. Bulanzhe

[Figures referred to herein are appended]

NOVEMBER SESSION

The November session of the Department was held in the House of Scientists.

S. E. Frish read a paper written by himself and Yu. M. Kagan, "Spectroscopic Study of the Movement of Ions on the Positive Pole of a Gas Discharge."

The method of sounding characteristics does not make it possible to form an idea of the nature of the movement of ions in a plasma since the relatively weak ionic current on the sounder is always swamped by the stronger electronic current. The authors have worked out a spectroscopic method for studying the movement of ions in gas discharge. The conditions were determined under which ion lines emerge in the vicinity of the positive pole, as ordinarily the positive pole emits only lines of neutral atoms.

It has been determined that, during discharge in argon, lines of positive ions can be obtained through use of gradual excitations. This type of excitation leads to a quadratic relationship between the intensity of lines and the density of the discharge current, which has been confirmed by direct photometric measurements.

The movement of ions caused by the electric field in plasma has two effects: displacement of lines and their expansion. In order to observe these effects, a special discharge tube was constructed, enabling observations at different angles to the capillary axis. A method has also been worked out for

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detecting, with the aid of the Fabry and Perot standard, small displacements of spectral lines. As a result of the measurement of spectrograms, the following experimental data were obtained.

1. In making observations along the electrical field, the lines of ions are displaced $\delta\lambda = 0.0010 \sim 0.0040$ Å, depending on the wave length under separated conditions; lines of neutral atoms do not show such displacement.

2. Lines of ions are wider than lines of neutral atoms under the same conditions of discharge.

It was necessary to determine whether the displacement was actually caused by the Doppler effect due to a transfer movement of ions in the field and whether the expansion of lines was dependent on the character of their movement and not due to any other factor. For this purpose the relation of the displacement to the wave length λ and the angle θ, between the direction of the field and the line of sight, was determined. For the Doppler displacement

$$\delta\lambda = \lambda \frac{v}{c} \cos\theta, \qquad (1)$$

where v is the speed of the radiating center.

The measurements showed that in accordance with equation (1) the displacement $\delta\lambda$ is proportional to the wave length λ and proportional to cos θ. In this way the Doppler character of the displacement of ion lines may be considered as fixed.

The widening of lines may be due to a number of reasons, among which the most important one might be the influence of the internal field in the plasma. This widening depends on the extent of the Stark cleavage. For research purposes, argon lines were collected which do not disclose a noticeable Stark effect in fields ranging up to 10^5 v/cm. Thus the principal reason of widening of lines under our conditions, must be the Doppler principle, as a result of the movement of atoms and ions. The experiments showed that the contours of lines of neutral atoms have the usual Doppler character and grow narrow when the capillary is cooled by liquid air.

Further, a study was made of the relation of the displacement and widening of lines to the strength of the discharge current and gas pressure. The following results were obtained:

1. The rates of transfer movements increase with current density and reach a maximum under a pressure of about 1 mm Hg (Figure 1). The values of transfer rates lie within the range $1.0 \times 10^4 \sim 2.3 \times 10^4$ cm/sec, which is of the same order of magnitude as the heat transfer rates of atoms.

2. Gas temperatures, determined at half-width of the lines of neutral atoms, lie within the range of $900^\circ \sim 1600^\circ$ K, and with a lowering of pressure they disclose a steady and gradual decline.

3. The ion lines possess, under the same conditions of discharge, different widths when observed lengthwise along or crosswise to the capillary. The contours of lines within the limits of observational accuracy are symmetrical. The relationship between the half-width of ion lines and the pressure can also vary according to lengthwise or crosswise observation of the capillary. This points to the complex character of the movement of ions, different from the regular heat movement. If we nevertheless attempt to calculate "temperatures" at the half-width of ion lines, we obtain curves as shown in Figure 2. Curve 1 relates to lengthwise observations of the capillary and shows a peak corresponding to the peak in Figure 1. Curve 2 relates to crosswise observation of the capillary. The temperature increases steadily and proportionally to decreasing pressure.

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The entire results can be explained if we assume, in accordance with L. A. Sen's hypothesis, that the ions gather speed only along the length of a free passage and they are practically neutralized with every collision. In this connection, it is necessary to take into account the presence in the discharge tube of the lateral component of field intensity E_I, together with the longitudinal component E_{II}. The widening of ion lines during crosswise observation of the capillary is caused by their movement under the influence of this lateral component E_I, possessing a radial symmetry. The form of the lines, when observing along the axis of the capillary, can be understood only by simultaneously considering the heat movement and the movement caused by the field. This character of ion movement has been examined in the work of Academician V. A. Fok, whose calculations were used by the authors of the report. The theoretical contours of the lines are shifted and widened in accordance with experimental data. In moderate fields and at high temperatures (which corresponds to experimental conditions), they remain practically symmetrical. In large fields, asymmetry must occur.

For the mean value of the speed of transfer movement of ions along the capillary axis, we obtain the following equation:

$$\bar{v} = 7\cdot10^3 \left(\frac{T}{273}\right)^2 \left\{ \frac{E_{II}}{p\left[1+\left(\frac{E_{II}}{E_I}\right)^2\right]^{1/2}} \right\}^{1/2} \qquad (2)$$

Equation (2) gives values of velocity v of the same order of magnitude as the results of measurements of line displacement $\delta\lambda$. In addition, equation (2) makes it possible to explain the appearance of peaks on the curves of Figure 1. With a decrease in pressure p, the change in the component E_{II} is negligible, while the component E_I is considerably increased. Under a pressure $p = 1$ mm Hg, (at which the peak on curve 1 is observed), the length of the free path of ions appears of the same order as the capillary radius ($r = 0.5$ mm) and v ceases to depend on p. There remains only the dependence of $\bar{v}$ on E_I, which causes the drop in the curve. The widening of ion lines, when observation is made along the capillary axis, is caused by the fluctuation in the lengths of free passages of ions. The location of the maximum on curve 2 (Figure 2) is likewise dependent on the limitation of the length of free ion passage by the dimensions of the capillary.

The second report on the subject, "Theory of 'borderline' Crystals," was made by S. I. Pekar.

By "borderline" crystals are meant alkali halide crystals, which are specially treated (by exposure to X-rays, ultraviolet, or cathode rays; heating of the alkali metal in vapors; introduction into the crystal of electrons from without) and, as a result, acquire a new band of light absorption in that portion of the spectrum where the crystal was transparent before the treatment. With the appearance of a new absorption band, the crystal changes its color; it assumes color. The absorption of light in a new band creates photoconductivity.

Pekar explained the creation of a new absorption band by the formation of local electron states in the crystal. These took place in the prohibited energy zone of the so-called F-centers. The analysis of extensive experimental material has led to the conclusion that the F-center is an electron which has been localized in the vicinity of a halide "hole" (a node of the lattice, abandoned by the halide ion).

Pekar has calculated the energy levels and ψ-functions of the electron in the F-center, the intensities and frequencies of light absorbed by the F-centers, the dependence of photoconductivity and dark current of colored crystals on temperature, energies of thermal dissociations of the electron, and he has determined the effective masses of electron in alkali halide crystals. The theory is in agreement with experiments.

Pekar's work has provided qualitative explanations for the coloring process by means of different treatments [illegible] in coloring; the width of the absorption band has been estimated.

The distinguishing feature of the theory is the establishment of an essential difference between the energy of light quantum, causing electron migration, and the energy of heat activation for the same period. This difference is confirmed by experiments.

Pekar has shown in his work that the generally known "zone" states of electron conductivity are fluctuating; they do not correspond to the minimum nor the extreme maximum energy of the crystal. From this state the electrons must inevitably change over to a state of "polarons," which can move in the electric field and are apparently the basic current-carriers during electronic conductivity of ionic crystals.

DECEMBER SESSION

At the December session of the Department, reports were heard from scientific workers of the Geophysical Institute of the Academy of Sciences USSR. E. F. Savarenskiy, Candidate in Physicomathematical Science, read a report, "Direction of Approach of Seismic Rays and Study of the Earth's Structure."

In seismology, the time of passage of seismic waves is used in studying the earth's inner structure. A very interesting attempt has been made to solve this question by using facts regarding the direction of seismic waves approaching the seismographs ("angle of approach of seismic radiation"). The foundation for such research was laid by Academician B. B. Golitsyn. Savarenskiy continued to develop the theory of this method and carried out a number of research experiments. The direct method of determining the approach angles of seismic radiation is as follows: during the passage of a longitudinal wave, there arise in the earth's surface reflected longitudinal and lateral waves, and the earth's surface is involved in a complicated movement. The relationship between the direction of dislocation of a portion of the earth's surface (angle $\bar{e}$) and the actual direction (angle e) of the seismic ray is obtained from the following condition

$$\cos e = \frac{v_p}{v_s} \cdot \cos \frac{90^\circ \; \bar{e}}{2}, \qquad (1)$$

where v_p and v_s are the velocities of the propagation of the longitudinal and lateral waves at the earth's surface. By determining the vertical (w) and horizontal (u and v) dislocations from the recordings of the vertical seismograph and two correspondingly orientated horizontal seismographs, the angle $\bar{e}$ can be determined from the following expression:

$$tg\,\bar{e} = \frac{w}{\sqrt{u^2 + v^2}} \qquad (2)$$

Then, knowing v_p and v_s, angle e can be determined from (1).

In order to obtain initial data, it is necessary to use seismographs absolutely identical in their characteristics. This requirement necessitated a great amount of work, especially at the "Moskva" seismic station, in studying the equipment and making it identical. The seismographs which recently have been constructed under the guidance of D. P. Kirnos and N. V. Veshnyakov are very useful in this respect, as they record the components of ground dislocation without distortions.

E. F. Savarenskiy has conducted research work in determining the angles of approach of seismic reaction with the aid of data from the "Moskva" seismic station (equipment of B. B. Gol[illegible]) and "[illegible]" seismic station (equipment of D. P. Kirnos). In the latter case, it was possible to determine certain anomalies in the structure of the earth's crust in this region (Tadzhik SSR).

In his report, "Contemporary Seismic Equipment," N. V. Veshnyakov, Candidate in Physicomathematical Science, gave an account of new seismic equipment.

In addition to the reports mentioned above, a report was given by E. M. Kondorskiy, Doctor of Physicomathematical Science, on the subject, "Theory of the Magnetic Properties of Polycrystalline Substances."

JANUARY SESSION

At the following session of the Department, which took place 24 January, two scientific reports were heard. The first report was given by A. Ya. Khinchin, corresponding member of the Academy of Sciences USSR, on the subject, "General Theory of Linear Diophantine Approximations."

The foundations of the theory of linear Diophantine approximations were laid by the classic works of Dirikhle, Chebyshev, and Kroneker. Dirikhle completely solved a homogeneous problem, whereas Chebyshev and Kroneker obtained the first basic results in the field of a considerably more difficult heterogeneous problem, which has been the object of almost all subsequent studies. The fundamental result obtained by Kroneker was the determination of conditions under which the given system of linear equations can be approximately solved, with any degree of accuracy, in integers. The problem in this case was given only as a matter of principle. The question of the magnitude of variables necessary for this purpose was not investigated. On the other hand, Chebyshev, limiting himself to the case of one equation with one unknown, established important quantitative regularities for this one instance, which connect the accuracy of approximation with the magnitude of the variable necessary for obtaining this accuracy.

During the subsequent several decades, the efforts of scientists were directed mainly toward the solution of various quantitative problems connected with the general problem of Kroneker, using any number of equations with any number of unknown values.

Only recently, Khinchin was able to find a complete solution of the quantitative problem in its most general form. A criterion has been found which was necessary and sufficient in order that the given system of linear equations may admit of solution with any degree of accuracy, with the additional condition that the variable values should not exceed the limits arbitrarily set, depending on the required degree of accuracy. From this criterion, in the nature of individual instances or simple conclusions, nearly all results which have been known until now in this field, as well as many new ones, are obtained.

With regard to Chebyshev's problems, complete clarity for the most general instance has recently been attained. The results of this work will be published in the near future.

The second report, "Structure and Development of Star Systems," was given by B. V. Kukarkin, Doctor of Physicomathematical Science. Kukarkin gave a systematic analysis of the numerous and various observations accumulated during the past years which were connected with the study of the structure of star systems.

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It may be considered as an established fact that all separate discrete systems in space represent star systems, combined in some proportion or other with matter in a state of diffusion (gas, dust); thus, Jeans' opinions on the sequence of forms of extragalactic nebulae must be finally discarded.

One of the simpler ways of studying the structure of our star system (Milky Way) is the analysis of calculations of the number of stars in relation to their visible brilliance. This method leads to a numerical solution of the basic integral equation of star statistics, the most practical of which is the one suggested by M. A. Vashakidze.

Kukarkin applied Vashakidze's method to a number of objects, the luminosity of which may appear constant in the first approximation. The numerical solution of the first integral equation of star statistics may be considered accurate. It appeared, however, that in regard to the distribution of spatial density certain objects in our star system form completely different subsystems. There is complete agreement between the observed distribution of density and the predicted theoretical distribution from the viewpoint of dynamics of the star systems.

The study of the formation of star systems nearest to us undoubtedly proves that their structure is no less complicated than the structure of our star system.

It may be considered as an established fact that the process of star formation continues up to the present time. Particularly convincing arguments in this regard were recently presented by V. A. Ambartsumyan, Corresponding Member of the Academy of Sciences USSR. There is no doubt that the various subsystems which we observe in our star system represent objects of different origin and age. On the basis of analysis of a number of data regarding the kinematic peculiarities and physical properties of certain objects, it may be stated that the "flat" subsystems, forming spiral branches of star systems, are fairly recent formations, whereas the objects forming elliptic nebulae and nuclei of spiral nebulae are older formations.

It is interesting to note that elementary statistical calculations undoubtedly show that spiral nebulae are a very rare type of object as compared to elliptical nebulae. Spiral nebulae considerably exceed elliptical nebulae, both in regard to their luminosity, as well as their solid mass. Apparently, the spiral structure represents a fairly recent formation in the more massive star systems. At the present time it is not yet possible to speak with certainty of the origin of stars of certain age characteristics, but one of the possible ways of formation of "young" stars is the condensation of dark matter. On the other hand, "dark matter" itself is often formed by matter thrown off by stars. It is possible that in star systems a highly complicated process of matter rotation takes place.

SEISMIC OBSERVATIONS DURING HEAVY EXPLOSIONS IN TRANSCAUCASIA

In developing the work performed earlier in 1947 (see *Vestnik Akademii Nauk SSSR*, No 4, 1947, page 91), the Transcaucasian Seismic Expedition of the Geophysical Institute of the Academy of Sciences USSR, in cooperation with the Institute of Physics and Geography of the Academy of Sciences Georgian SSR, continued its activity until the end of 1947.

In view of the great complexity of the geological structure of the Caucasus, the material accumulated by the seismic stations does not give a complete picture either of the physical properties of the strata where the spreading of seismic waves takes place or of the structure of lower parts of the earth's crust. In order to solve these problems, it is convenient to make use of seismic observations which were made during heavy explosions, as the latter are transferable from natural conditions to conditions closely connected with experiments.

During 1947, the expedition made observations during three heavy explosions (260, 360 and 550 tons of explosives) which were carried out for industrial purposes. Although the explosions did not take place in the same location, the initial assumptions which were confirmed by a preliminary study of the material obtained establish the possibility of generalizing the observations and the conclusions made from them.

The temporary seismic stations established for observation purposes were located in the Main Caucasian Range in the Riono-Kurinskaya depression between Zugdidi (Georgian SSR) and Geokchay (Azerbaydzhan SSR). The total area of the site where observations were made covered [illegible] kilometers.

The synchronization of the work at the stations and the detonation of the explosion was made with the aid of a radio transmitter in Tbilisi.

The special basic equipment of the expedition consisted of highly sensitive, high-capacity, vertical seismographs installed at stations distant from the point of explosion, and vertical optical seismographs with a much lower amplification factor. Seismographs of the latter type were installed at closer distances.

In order to describe the relative sensitivity of the equipment we may point out that at one of the stations, located at a distance of 60 kilometers from the point of explosion (explosion of 260 tons), the seismograph of the first type registered beyond the scale (amplitude over 10 centimeters) at the onset of the very first groups of seismic waves, whereas the seismograph of the second type recorded these oscillations with an amplitude of a few millimeters.

In addition to the above-mentioned equipment, the expedition had two sets of electrodynamic seismographs, each of which consisted of three sets: one vertical and two horizontal seismographs. The recording of seismic waves made by these seismographs, which are similarly oriented, makes it possible to calculate the complete vectors of ground dislocation and also to determine their change during the passage of seismic waves. With the aid of the above-mentioned ~~equipment~~, observations were made at five points at various distances (from 15 to 80 kilometers) from the point of explosion. A comparative study of these recordings is possible due to the fact that they were made with the same type of equipment.

A total of 25 observations were made in the course of three explosions.

The expedition completed its work at the end of November, but up to the present time the material has not yet been completely evaluated. However, the preliminary results make it possible to draw a number of general conclusions:

1. On the basis of the seismic data obtained, a hodograph of longitudinal and lateral waves was constructed, making use not only of the first onset of seismic waves, but of numerous following ones. The characteristic feature of the given hodograph is the fact that it is constructed on both sides of the source of oscillations which makes it possible to determine not only the apparent velocities (depending not only on the physical properties of the rock strata, but also on the inclination of the strata), but also the actual velocities of diffusion of seismic waves in certain plutonic strata of the earth's crust. The hodographs of seismic waves represent the basis for interpreting the observations of seismic stations. With their help, all seismic elements are determined: the location of the epicenter and seismic hypocenter, the initial time in the nucleus of the earthquake, the propagation velocity of seismic waves in one or the other direction, the structure of the earth's crust in a certain region, etc. Until now no detailed hodograph had been set up for the Caucasus in the case of near earthquakes. Therefore, the

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results of the expedition's work are an essential contribution to seismic research work in the Caucasus.

2. On the basis of observations, it is possible to determine the strata structure (depth, inclination, propagation velocity of seismic waves, etc.) of the earth's crust in the Caucasus Mountains. The final numerical data will be obtained as a result of a final revision of the material on hand.

3. The seismic observations which have been made establish an abnormally strong absorption of seismic waves when they spread in a meridional direction (from the north to the seismic station at Yerevan).

It is proposed that the further work of the expedition (in 1948) be concentrated on obtaining seismic material relating to the diffusion of seismic waves in a meridional direction. Such research work is particularly important at this time, when we have the basic material on questions of seismic-wave propagation in a latitudinal direction.

THE GARM EXPEDITION

In continuation of the earthquake study started in 1945 by the Geophysical Institute, research work was carried on in the summer of 1947 in Obi-Garm, using new equipment constructed in the Institute. (The new equipment included epicentral seismographs designed by D. P. Kirnos and D. A. Kharin, extensometers of N. V. Veshnyakov, and new types of inclinometers designed by V. F. Bonchkovskiy.)

The Garm Expedition of 1947 was composed of three geological working details. The detail under the direction of I. Ye. Gubin compiled large-scale maps of the basic tectonic disturbances and worked out detailed geological cross sections intersecting the more active areas of seismic disturbance in the region of Tadzhikistan. The second seismogeological detail (group leader, S. V. Medvedev; scientific supervisor, G. P. Gorshkov) carried on investigations of the consequences of destructive earthquakes (Dzhelalabad, 2 November 1946; Andizhan, 2 June 1947). As a result of this work, the division into districts of the northwestern part of Tyan'-Shan', according to seismic disturbances, has been made more precise and some recommendations have been made for improving the earthquake-proof condition of houses, as well as for the proper location of industrial buildings.

One of the more interesting problems in the general problem of orogeny is the establishment of basic laws in the distribution of elements in the inner structure of folding strata on a background of large tectonic forms and their relationship with one another. The main purpose of such research work is to ascertain the character and direction of movement of matter within the strata in orogenic processes.

Research on this problem was carried out by the third tectonic detail (group leader, I. V. Kirillov; scientific supervisor, Prof V. V. Belousov). The group made detailed investigations of the structure of argillocalcareous strata of the Upper Chalk period and the paleogenetic system in the Vakhshskiy Khrebet. Interesting material has been accumulated in the study of microstructures. In the region studied, indications were disclosed of differential sliding, expressed in the form of acute dislocations and disharmonies of various dimensions.

The main problem of gravimetric research was the study of possible variations in the energy field in connection with geodynamic processes taking place in the earth's crust. The work of this detail (group leader, Yu. D. Bulanzhe) during the first 2 years consisted of determining a high-precision pendulum station in Obi-Garm for the purpose of obtaining data on the starting period. In comparing the data obtained with the measurements made in the course of several years or after a heavy earthquake one will be able to judge the changes of gravity in Tadzhikistan in relation to the Central Russian plateau. The measurements were carried out with [illegible] five pendulum instruments; methods were worked out for precise pendulum determinations. In 1947, the gravimetric detail made over 100 determinations of gravity with profiles intersecting the more active seismic regions -- Khrebet Petra Pervogo (Range of Peter the Great), the Gissarskiy, Darvazskiy, and Karateginskiy mountain ranges. The measurements made give more precision to the existing ideas on local anomalies of gravity and enable us (in using the data of geological research) to judge regarding the [illegible] of the contact surface of crystallic rocks and recent Tertiary deposits. The latter is of particular interest, as it may be assumed that this contact surface is responsible for the greater part of small-radius earthquakes.

The purpose of the work of the magnetic detail was the study of regional anomalies in the secular course of magnetic elements in connection with physical phenomena determining the seismic character of a certain region. These observations were made at the suggestion of the Garm expedition by the Sceintific Research Institute of Terrestrial Magnetism, Main Administration of Hydrometeorological Service under the Council of Ministers USSR

The next important problem coming within [illegible] research work carried on by the Garm expedition is the study, by geodetic methods, of residual deformations of the earth's crust, both of a secular character and those caused directly by earthquakes.

The research program includes the study of vertical and horizontal relative movements of the earth's crust. It is intended to detect the vertical movements by high precision leveling. For this purpose, leveling courses were chosen with an extension of over 500 kilometers, intersecting the fundamental tectonic disturbances in the territory of the Tadzhik SSR. Along these courses, on an average of every 4 or 5 kilometers, datum points of different types were established, the relative shifting of which points should reflect the movements of the earth's crust.

The most difficult problem was the establishment of geodetic measurements for the study of horizontal movements caused by the overthrust of Mesozoic strata of the outer arc of the Pamirs on the Paleozoic mountain range of the Gissarskiy Khrebet. For this purpose it is intended to lay highly accurate first-order triangulation points in the direction of Kulyab-Stalinabad-Ura-Tyube, as well as several high-precision transverse courses. During this working season, the preliminary survey and construction of centers has been completed in the Kulyab-Stalinabad section, as well as the preliminary survey of the transverse courses.

The geodetic work is carried out by the Main Administration of Geodesy and Cartography under the Council of Ministers USSR according to plans developed in collaboration with the geodetic group of the expedition (Prof V. V. Danilov and Yu. D. Bulanzhe). In order to carry out a number of stationary observations (seismometric, observations in connection with the variations of incliniation in the earth's surface, of ground deformations due to the passage of seismic waves, micromagnetic variations in the earth's field, and periodic variations of the gravitation field), which proved to be very important during the period of the expedition's work, it was necessary to establish a well equipped geophysical station. With this purpose in mind, the Garm expedition undertook the construction of a special horizontal tunnel in solid granite, in one of the sections of the Garm region which is subject to frequent and intensive earthquakes. The projected length of the passage is 50 meters. At the end of the tunnel it is planned to build several workrooms for keeping the necessary equipment. The breaking of the tunnel has already been started, and the passage should be ready for use by the opening of the next working season. It is planned to construct near the tunnel, a station building which will house the recording devices, as well as provide living quarters and other rooms.

[Appended figures follow.]

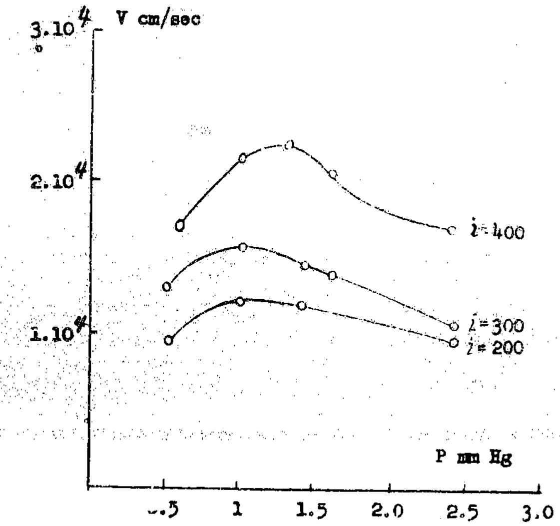

Figure 1

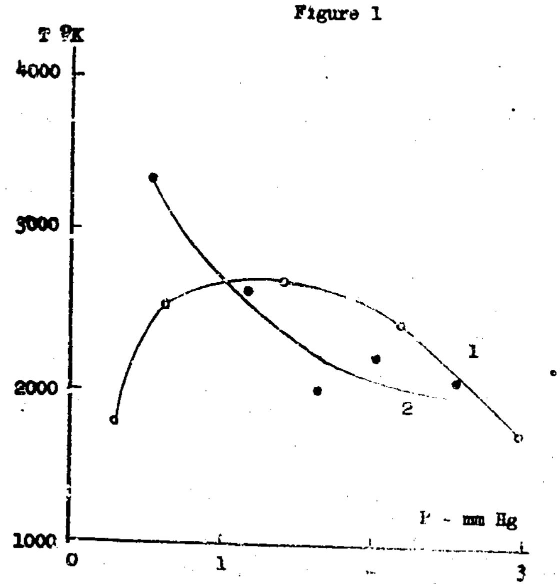

Figure 2

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